Floodplain Restoration for Fish and Wildlife Habitat on the Upper Mississippi River

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Abstract

In its natural state the Mississippi River planform consisted of a main channel, secondary channels, a floodplain, and natural levees that separated the channels from the floodplain. For river flows near bankfull, the hydraulic slope of the river and fluvial processes in the channels such as erosion and deposition reached a maximum. For river flows well above bankfull (ie. flood conditions), the natural levees were submerged resulting in water and sediment conveyance in the floodplain. The majority of the conveyance continued to be in the channels though, since floodplain resistance was much higher than in the channels.

Construction of the locks and dams on the Upper Mississippi River submerged the natural levees and floodplain creating navigation pools upstream of the dams and leaving only the higher parts of the natural levees as islands. A minimum water level was established for commercial navigation, which eliminated the summer low flow condition critical for healthy marsh vegetation. Submergence caused changes in the vegetation communities resulting in decreased floodplain resistance and increased floodplain conveyance with time. For river flows near and well above bankfull, the majority of the conveyance is now in the floodplain in the lower reaches of the navigation pools. This has decreased the hydraulic slope in the pools and caused a shift towards a more depositional system. Wind driven wave action has become a much more significant factor in the floodplain affecting both the transport of sediment and morphological changes in the floodplain. Many of the islands that were formed in the lower pools subsequently eroded due to wave action. Sediment transport in the floodplain now is affected by daily wind conditions as much as seasonal variations.

By constructing islands, the natural levees that were eroded by wave action are being restored. This separates the main channel and secondary channels from the floodplain of the river for flow conditions below bankfull. Islands reduce floodplain conveyance and restore the hydraulic energy in adjacent channels necessary for erosion and transport of sediment. Islands reduce wave action in the floodplain and erosion on shorelines.

Water level drawdowns restore the low flow conditions that once dried out the floodplain. This is an important process in the life cycle of many of the plants and animals that live

in the Mississippi River floodplain. The mudflats and sandbars that are exposed during a drawdown provide important habitat that is currently missing in the lower pools. Various species of aquatic plants colonize the dried out mudflats and sandbars.

Introduction

Over the last decade, five miles of islands have been constructed in the floodplain of lower Pool 8 to restore fish and wildlife habitat. Large barrier islands were positioned to alter flow patterns and reduce wind-driven wave action. Smaller structures, called seed islands, were constructed to create alternating zones of deposition and erosion where islands and channels will form. The island top elevations varied from the bankfull flood to the 10-year flood. Islands at the bankfull elevation were constructed of rock and allow flood conveyance through floodplain areas that are normally isolated during low flow conditions. Shoreline stabilization on earthen islands was done with rock, woody plants, and native grasses.

In the summers of 2001 and 2002 water levels in pool 8 were drawn down 1.5 feet, partially simulating the annual low flow conditions that occurred prior to lock and dam construction. The mudflats and sand bars that were exposed were extensively used by shorebirds during the drawdown period. Preliminary monitoring results indicate a significant vegetative response in lower pool 8 to the drawdowns. This provided habitat to thousands of waterfowl during the fall migration.

Island construction was funded through the Upper Mississippi River Environmental Management Program. The water level drawdowns were funded through the St. Paul District's operation and maintenance budget for the 9-foot navigation channel and by natural resource agency support. Planning and design for these efforts was done by an interagency team that included the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, the Wisconsin Department of Natural Resources, and the Minnesota Department of Natural Resources. Biologists and engineers worked together to establish habitat goals, management objectives, and project designs.

Criteria

A number of physical criteria was established for these efforts. The ratio of floodplain to total river discharge (Q_f/Q_t) in the project areas was reduced to values as low as 0.002 to create sheltered floodplain habitat. Wind fetch was reduced to less than 4000 feet if possible, though other factors such as the location of historic islands was a bigger factor in positioning islands. The maximum drawdown allowed was 1.5 feet. This criteria was established based on the navigation channel dredging capability and cost, and to limit impacts to recreational boaters.

Biologic criteria was established for different habitat types. For instance sheltered overwintering habitat for Bass and Bluegills required velocities less than .015 fps, winter water temperatures from 0 to 4 degrees Celsius, dissolved oxygen concentrations greater than 4 mg/L, and depths greater than 4 feet. The criteria for migratory waterfowl was less specific. Shallow protected habitat with velocities less than .15 fps, and significant amounts of woody structure, provides habitat for puddle ducks. Diving ducks on the other hand used deeper habitat with higher velocities as long as food was present.

Island Layout

Figure 1 is a plan view of islands that have been constructed in lower Pool 8 of the Upper Mississippi River. Islands were positioned along channels and island remnants to rebuild the natural levees that were submerged by dam construction and eroded by wave action. This reduced floodplain conveyance and restored more dynamic fluvial processes in adjacent channels. Some portions of the islands were positioned near channels with water depths in excess of 5 feet to provide access for construction equipment. Islands were positioned to shelter the maximum amount of shallow (less than 3 feet deep) water area, where aquatic vegetation growth is most likely to occur. Sheltered deep water habitat was created by positioning islands so that existing deep water was sheltered or by dredging in areas sheltered by islands. Wind fetches were reduced to 4000 feet or less whenever possible, though other factors usually affected island position.

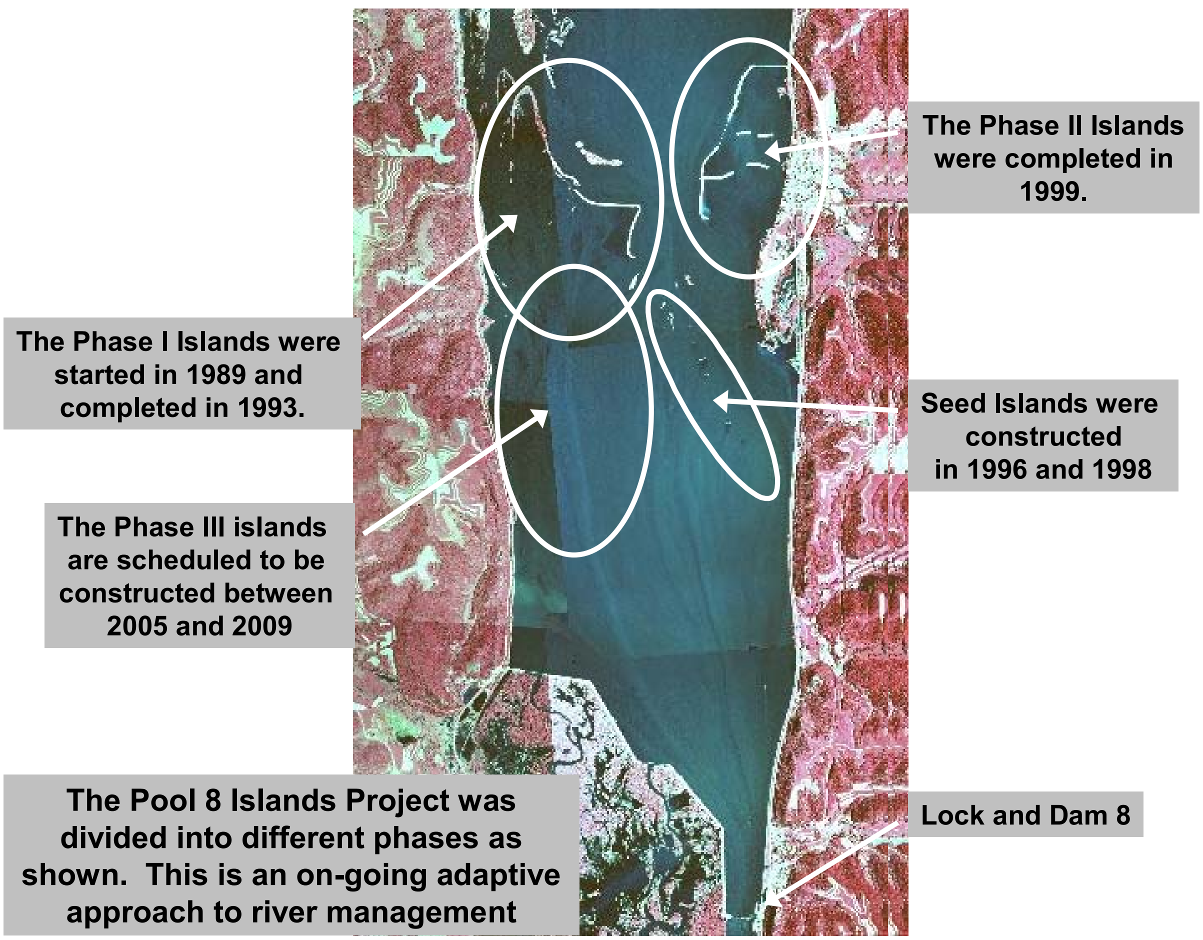

Figure 1. Island Layout

Island Cross Section

The island cross section used in the pool 8 design is shown in figure 2. This cross section consists of a sand base extending from the river bottom to an elevation 1 to 2 feet over the average water surface elevation, and a second lift of fine sediments, placed on top of the sand base to a thickness of 2 to 4 feet. The fines consisted of a mixture of about 50-percent sand and 50-percent silts and clays. The sand base provides a stable work surface for construction equipment and is needed to form a stable littoral zone and beach. The fines provide topsoil to support the growth of woody and grassy vegetation which stabilizes the islands and provides habitat. As-built and final berm profiles are depicted in figure 2 because, wave action on the shoreline usually redistributes sand to a much flatter slope than it is placed at. Approximately 75-percent of the island fill material consists of sand size sediments. Sand was dredged from riverine sources including sand deposits in the floodplain and channels, while fine sediments were obtained exclusively from deposits in the floodplain. While dredge cut layout was usually based on the availability of suitable construction material, consideration was also given to creating beneficial deepwater habitat.

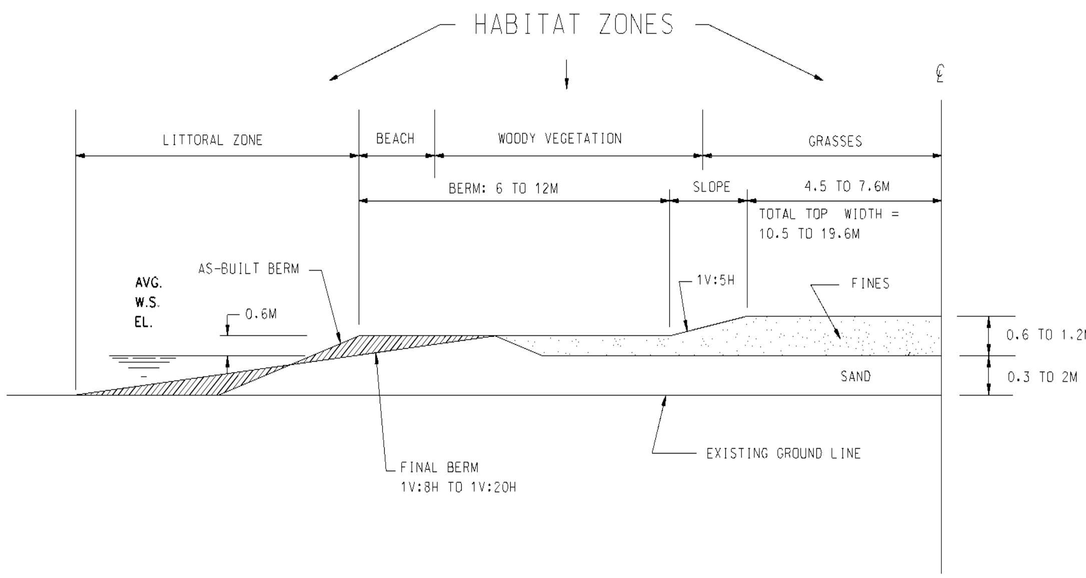

Figure 2. Island Cross Section Detail.

Islands should be constructed with a top elevation near or above the bankfull elevation (approximately the 1.5-year flood event). As bankfull conditions are approached and exceeded, the islands are overtopped and flow through the floodplain increases. However, since floodplain resistance is much lower now, floodplain conveyance might increase to undesireable levels, so island elevations higher than bankfull were often chosen to maintain a lower ratio of floodplain to channel discharge during floods. Island elevations in pool 8 varied from the 2.5-year flood to the 10-year flood. Rock spillways replaced earth islands in several locations to provide floodplain flow when river discharge exceeds the 1.5-year flood event.

The hydraulic slope across an island, flow velocity, and potential for erosion decreases with increased island width. To achieve a floodplain to total discharge ratio (Q_f/Q_t) less than 0.5 during floods, the width of an island can be increased and the roughness maximized by maintaining woody vegetation on it. Top widths used in Pool 8 varied from 30 to 90 feet and base widths varied from 90 to 200 feet.

Side slopes of islands were set at 1V:5H or flatter to reduce rill erosion due to rainfall runoff and to provide better terrestrial habitat. In reaches where riprap is used, side slopes are set at 1V:3H or less to reduce rock quantities.

Shoreline Stabilization

Shoreline stabilization falls into 3 categories; riprap, biotechnical, or vegetative. Riprap is used on shorelines exposed to significant flow velocities and on convex shorelines such as island tips. Riprap consisting of a 1.5 foot layer of rock performed well during the 1993 flood when sustained winds in excess of 40 miles per hour occurred.

On shoreline reaches where wave action is the dominant erosive force, biotechnical stabilization is used. This technique involves construction of a 20 to 40 foot wide earth berm with a design elevation of 2 feet over the average water surface. Wave action on shorelines with sand substrate will result in offshore beach slopes of 1V:10H or flatter. The goal in most instances is to construct a wide enough berm so that after a stable beach has formed, at least 15 feet of the berm remains as substrate for woody vegetation growth. In shallow water (e.g. 2 foot depth or less), a 20 foot berm width may be adequate, while in deep water (greater than 4 foot depth) a 40 foot berm may be needed. In reaches that are extremely sheltered, vegetative stabilization of the berm was used. This consists of planting willows or similar species on the berm. On reaches exposed to significant wave action, rock groins were constructed perpendicular to the berm to prevent longshore transport of sand. Groins are usually 20 to 40 feet long, have a 3 foot top width, 1V:1.5H side slopes and are spaced at a distance equal to 6 times the groin length. Offshore rock mounds can be used instead of groins to add diversity to an island shoreline, however rock mounds are much more expensive than groins. Woody vegetation is planted near the back of the berm for stabilization purposes however natural colonization by woody vegetation also occurs.

If severe ice action is expected, berm widths should be increased and rock slopes should be reduced. Based on our experience, if ice action is expected to be a problem, berm widths should be increased to 40 feet or more and rock features should be constructed with 1V:4H slopes or flatter.

Water Levels

Figure 3 shows daily water levels at Lock and Dam 8 for the years 1993 through 2002. Water levels are between elevation 630 and 631 the majority of the time, however several major floods can be seen as spikes in water levels, especially in 1993, 1997, and 2001. Drawdowns of pool 8 were done in 2001 and 2002. This was the first time in over 30 years that water levels in the lower pool had been reduced this much. The resulting aquatic vegetation response was exceptional with exposed mudflats being quickly colonized. Physical and biological monitoring continues to determine the long-term effects of water level drawdowns, however the initial assessment by natural resource managers is that water level drawdowns should become part of future river management.. The major constraints encountered were maintaining the 9-foot commercial navigation channel and minimizing impacts to recreational boaters. These constraints were handled by over dredging the navigation channel prior to the first drawdown in 2001 and limiting the drawdown to a level that was acceptable to recreational boaters. The amount of sand dredged in 2001 was three times as large as that dredged in a normal year. However, no dredging was required in 2002, even though a 1.5-foot drawdown was done that year also. This is an important result since it indicates that overdredging during the initial drawdown year results in reduced dredging costs in future years.

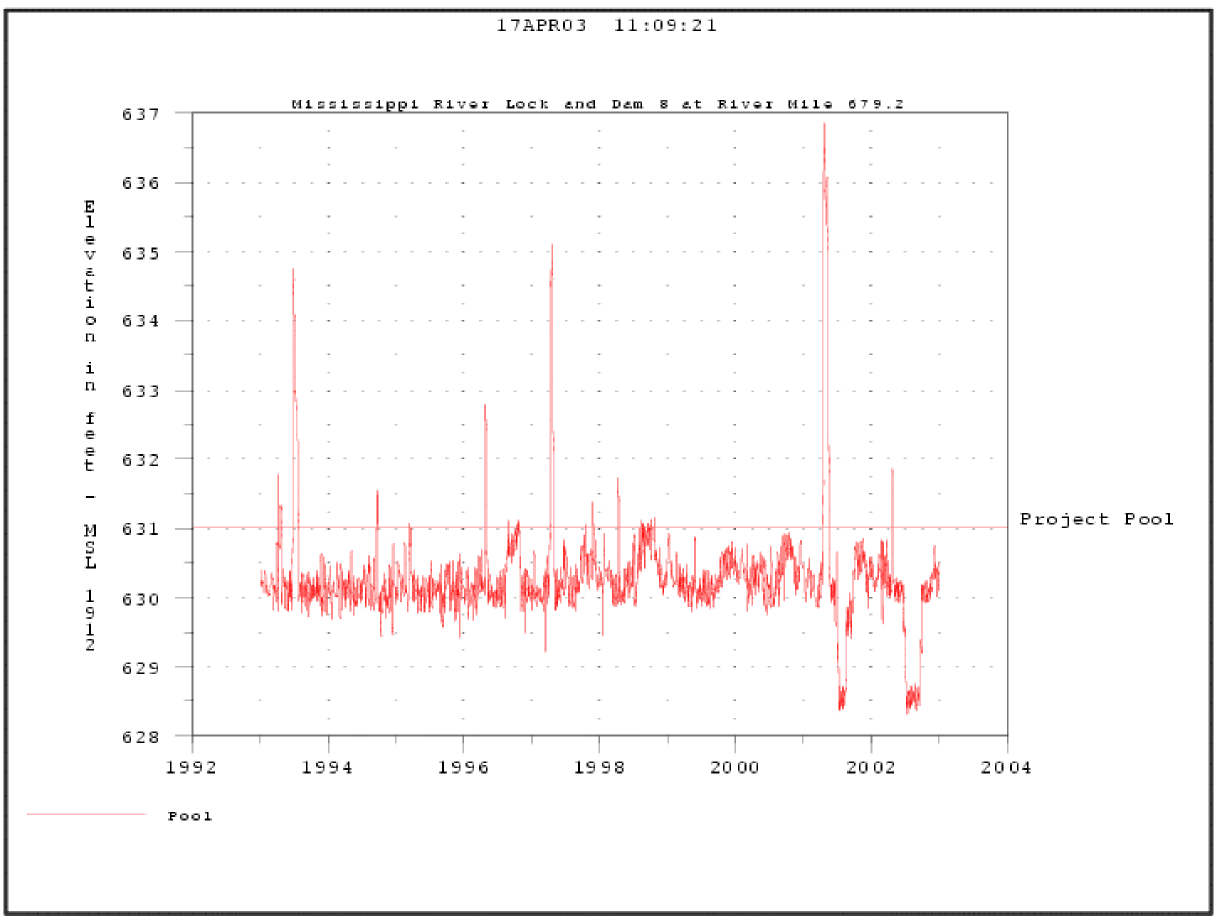

Figure 3 – Water levels at Lock and Dam 8, 1993 through 2002.

Main Channel/Floodplain Flow Splits

Figure 4 shows main channel discharge as a function of longitudinal position in pool 8. River mile 680 on the left side of the chart is the downstream end of pool 8, while river mile 702 on the right side of the chart is the upstream end of pool 8. In the upper half of the pool, from about river mile 692 to river mile 702, over 80-percent of the total river flow is conveyed in the main channel (percentage is read on the right axis). However in the lower half of the pool, main channel conveyance drops considerably, reaching levels as low as 30-percent. This is due to the many secondary channels and the efficient floodplain found in the lower half of the pool. A more desirable condition is to maintain over 70-percent of the total river flow in the main channel. Most of the dredging that is done in pool 8 is associated with the reduced main channel flow between river mile 687 and 690 (dredge cut location and volume is represented by the black bars). The increased floodplain flow in the lower half of pool 8, causes increased sediment load to the floodplain and changes the suitability of the floodplain for many species of organisms. Comparing preproject and postproject flow data, indicates that main channel flows have not changed significantly, due to increases in floodplain flow in the reach upstream of the islands. However, flow in the floodplain areas where the islands were constructed were reduced significantly, creating low velocity floodplain habitat.

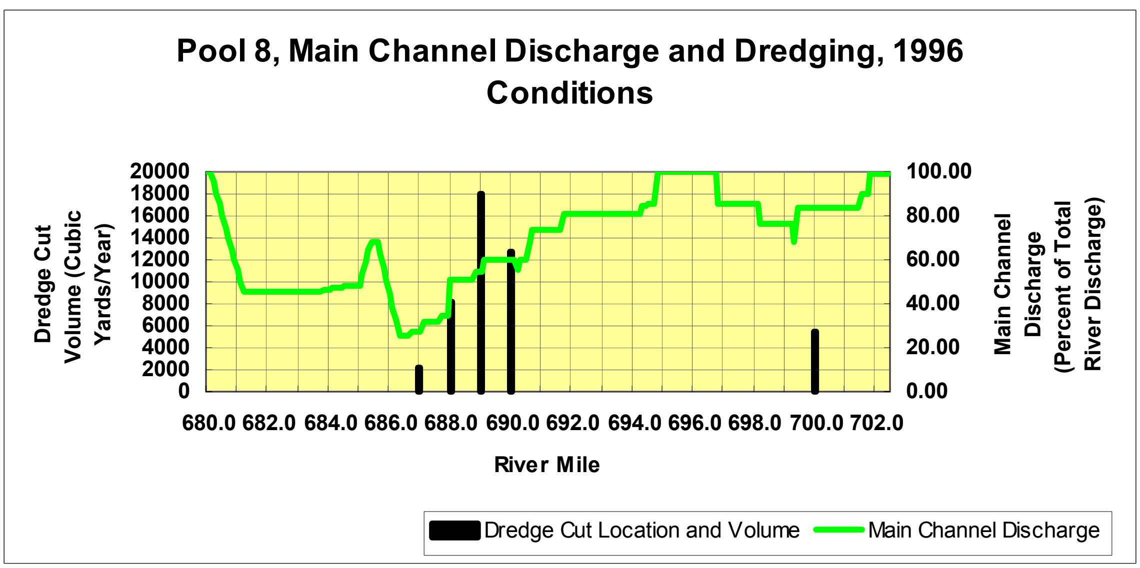

Figure 4. Main channel conveyance and dredge cut location in pool 8.

Wind Driven Wave Action

Wind driven wave action is a significant factor affecting sediment movement, water quality, and habitat on the Upper Mississippi River. In a truly riverine environment, wave action would not be a significant force. However in shallow, submerged, floodplain areas, such as those in lower Pool 8, wave-induced sediment resuspension occurs on a daily basis with peaks in suspended sediment concentration corresponding to the windiest part of the day. This causes reduced light penetration and is a limiting factor for growth and recovery of aquatic plants. Figure 5 illustrates wave growth versus wind fetch for a 25 mph wind and shows the effects of islands. Upon reaching an island shoreline, waves break, losing all of their energy, and then begin to grow again on the downwind side of the island. Islands minimize wave height, and create sheltered zones on the downwind side of the islands. This reduces sediment resuspension by wave action and provides thermal refuge for migrating waterfowl and other organisms.

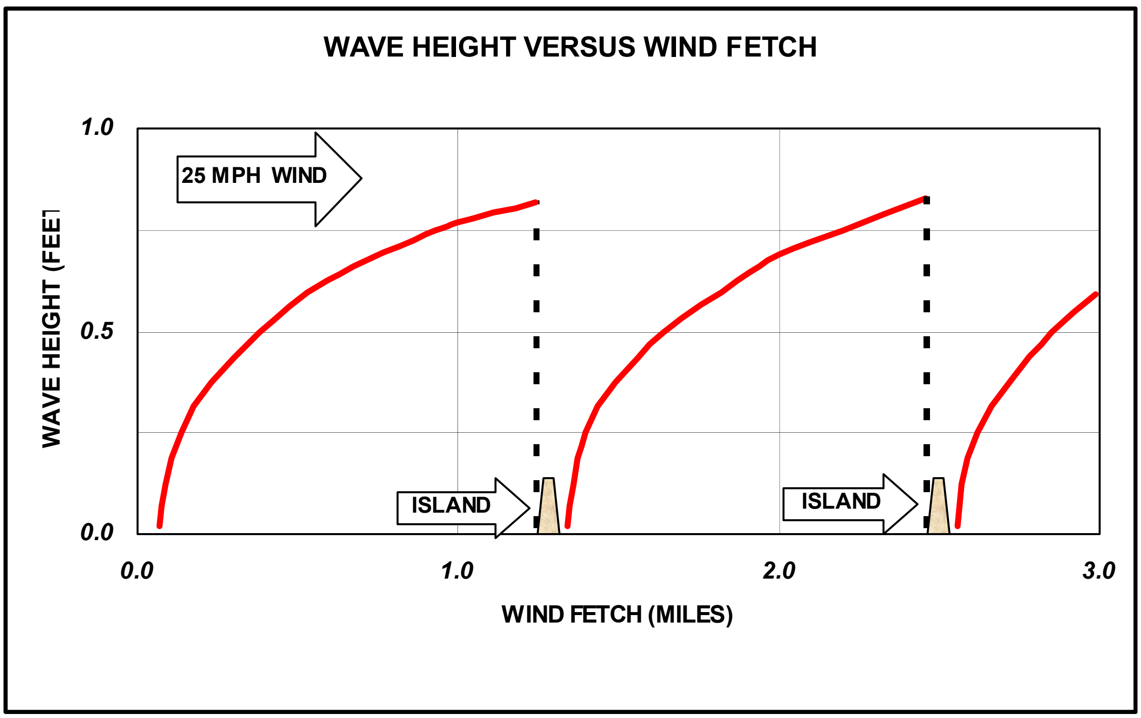

Figure 5. Wave growth and Island Effects.

Conclusion

The geomorphic form and hydrologic function in lower Pool 8 was improved through island construction and water level drawdowns. This has resulted in a significant improvements in floodplain aquatic and terrestrial habitat (Figure 6). Based on large floods that occurred in 1993, 1997, and 2001 the islands are stable and appear to have altered sediment transport in a beneficial manner. Sand bars are forming near the islands and wave action has been reduced. Biotechnical stabilization techniques used on the pool 8 islands were successful, and within a few years after construction, willow growth on the islands had spread from the water line to almost the top of the island, providing a 20 to 30 foot swath of willows. These designs are now standard on many of the projects constructed on the Mississippi River. Island costs varied depending on cross sectional size and construction technique, but most islands fell in the range of $250 to $300 per linear foot. Water level drawdowns of only 1.5 feet exposed sandflats and mudflats, which had not been dried out in over 30 years. These areas were quickly colonized by aquatic vegetation, which provided important habitat to migrating waterfowl. The visibility of this project to the thousands of people who use the refuge annually will increase awareness of the role annual water level fluctuations have in maintaining the health of wetlands. In turn, this will ease the challenge of implementing water level management on the Upper Mississippi River.

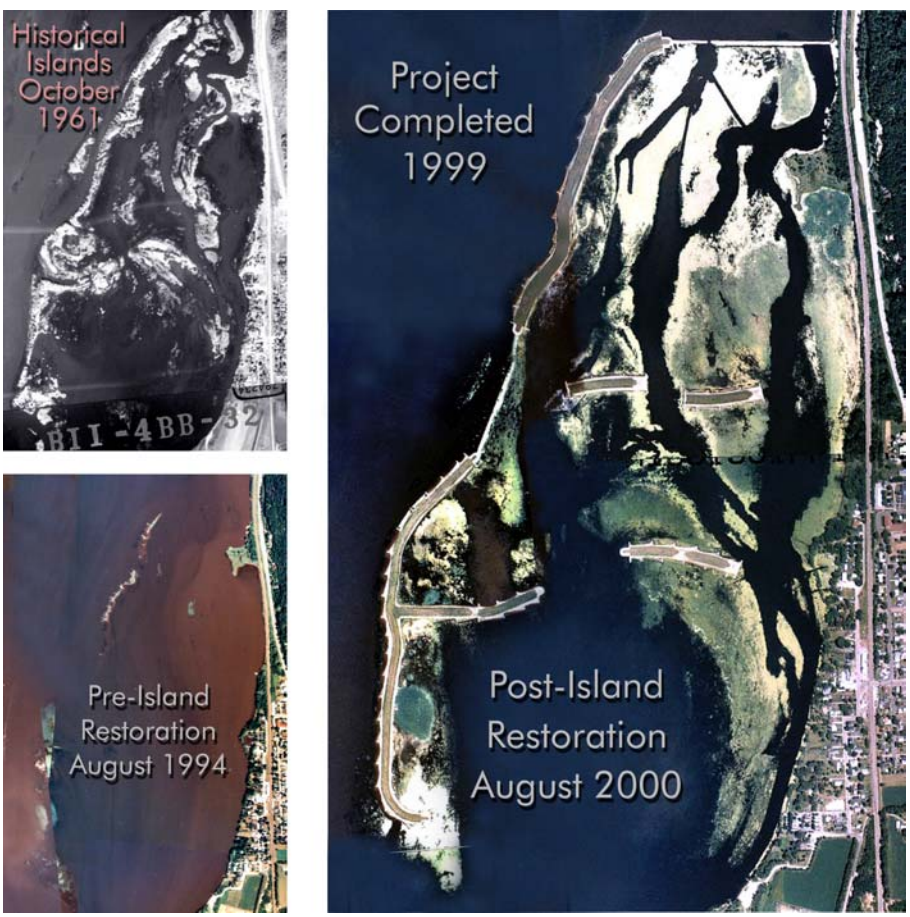

Figure 6. Aquatic Plant Response in Stoddard Bay in Lower Pool 8.